"A rule of thumb," he says, "is as good as a scientific law to a man who has played often and well enough to regard the rule of thumb as a necessary law of nature. Amateurs of less experience than this may find it much easier to obey a law the reason for which they have grasped."

The possible motions of a billiard ball here discussed are five, viz.: (1) Perfect rolling; that is, rotation about a horizontal line through the point of the ball touching the table for the time being. This is the motion assumed by the ball when struck by a horizontal cue in a vertical plane through the centre at a height 7/10 of the diameter. (2) Sliding without rotation. (3) Pure side; that is, rotation about a vertical axis through the centre. (4) Curving motion; that is, rotation about a horizontal axis through the point touching the table, such axis coinciding with the direction of translation. (5) Imperfect rolling; that is, rolling as in (1) combined with any of the others.

These probably exhaust all forms of the motion for gentle strokes. A hard struck ball will probably jump many times before it finally subsides into rolling or sliding, just as a cricket ball neither rolls nor slides much till it is nearly spent.

The most interesting case occurring in practice is that in which the striking ball with perfect rolling impinges on the object ball at rest. The problem of the motion of the two balls after impact involves the determination of the important constants. The constants are:—(1) The coefficient of elasticity, $1 - e$, between ivory balls, which, on authority accepted by the writer, is given as about 14/15. (2) The friction, f, between the balls, which is determined as follows:—The object ball, if struck obliquely, acquires from the friction with the striking ball a certain rotation about a vertical axis through the centre. This is proportional to f. With this is compounded a rotation about a horizontal axis due to direct impact, so that the resultant rotation is about an axis inclined to the horizon. And if we can guess the direction of that inclined axis, we can determine f. By using an old red ball, on which are irregular markings, as the object ball, Mr. Hemming says the inclination can be guessed with fair accuracy, and this method gives for f a value between 1/70 and 1/105.

A third possible constant is that of the impulsive friction between ball and cloth, denoted by μ. This Mr. Hemming retains provisionally in his formulæ, but ultimately rejects as inappreciable.

In the case of impact between ball and cushion, the action of the cushion varies so greatly with the speed, as well as with the direction, of the striking ball, that no constant can be determined.

Probably the most useful part of the book to the practical player is Appendix II., on the *margin of error* in billiard strokes, from which even the best player may learn something to his advantage. I select the following instances: in playing a winning hazard, the margin of error is least, and the stroke most difficult, when the object ball is half-way to the pocket. It is found also that the margin of error is smaller in a thin losing hazard than in the corresponding through stroke.—But is not the management of the cue more difficult in the latter case?

Appendix I. treats of the effect of nap on a ball played with side. It raises the question of the nature of rolling friction. According to Prof. O. Reynolds (*Phil. Trans.* 1876), rolling friction may be reduced to sliding friction. When a body rolls on a plane, expansion or contraction takes place in the substances immediately in contact, which, or the subsequent restitution, causes one to slide over the other. Sliding is thus always being created and destroyed by friction as fast as it is created. Mr. Hemming makes a different hypothesis—namely, that the cloth may be regarded as a series of stiff parallel ridges, facing the way of the nap. The rolling ball is instantaneously in contact with two of them, say, at the points P and P′, the line PP′ subtending at the centre a very small but finite angle, which depends on the nature of the cloth. Through P and P′ pass two reactions, which intersect (he says) in the vertical through the centre at the height 7/10 of diameter, and therefore cause the ball to continue perfect rolling. He is not writing a treatise on rolling friction, and does not therefore give any *a priori* reason why the two reactions should intersect at the point stated. *A posteriori* they must do so, for otherwise the ball could not continue perfect rolling as, in fact, it does. It would not be difficult to show, applying what is known as Thomson's theorem, that on Mr. Hemming's hypothesis, as to the nature of the cloth, the ball would pass from the state of rotation round P to a state of rotation round P′ with diminished energy, and so must continue perfect rolling.

S. H. BURBURY.

OUR BOOK SHELF.

A Rudimentary Treatise on Coal and Coal Mining. By the late Sir Warington W. Smyth, M.A., F.R.S. Eighth edition, revised and extended by T. Forster Brown. Pp. vi + 346. (London: Crosby Lockwood and Son, 1900.)

NO man did more for the advancement of mining education in this country than the late Sir Warington Smyth. In 1851, when the Royal School of Mines was founded, he was appointed lecturer in mining, and he continued to give his annual course of mining lectures until June 20, 1891, when, sitting with his students' examination papers before him, he passed away—dying, as he had lived, in harness. In 1851 he found the art of mining in the trammels of empiricism; and, thanks to his wide practical experience and his familiarity with continental practice, he was able in his lectures to evolve order out of chaos, and to arrange heterogeneous facts in a comprehensive system. Moreover, his work underground as mineral inspector and adviser to the Crown enabled him constantly to keep his lectures abreast of the times. Unfortunately, he never prepared them for the press. But, while directing the higher education in mining, he was not forgetful of the needs of the elementary student, and was induced in 1866 to write for Weale's excellent series of rudimentary treatises a little book on coal and coal mining. This was eminently successful, and seven large editions were called for. No previous work gave so popular and yet so full and accurate a view of the subject. Written in a delightful literary style, it bore internal evidence of not being a mere extract of books, and afforded attractive reading not only for the unpractised, but also for the experienced mining engineer and geologist.

Since the publication of the seventh edition great progress in mining has been made, and the value of the

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book has necessarily greatly diminished. It is therefore most satisfactory to note that Mr. T. Forster Brown, an eminent mining engineer, and Sir Warington Smyth's successor as chief inspector of the mines of the Crown and of the Duchy of Cornwall, has edited a revised and extended edition, in which the principal changes and improvements in coal mining are treated. The chief additions made are two chapters dealing with blasting and explosives and with coal washing. In the latter, coke making (a subject usually included in metallurgical treatises) is also discussed. Mr. Forster Brown has very wisely been careful to retain the general character of the book. He has perhaps carried to too great an extent his unwillingness to alter the original text. The prices mentioned throughout the book, for example, refer to the years 1864-6. The Saxon coal production is given in the long obsolete units of *Scheffel*; and references are made to New Granada, a country that changed its name in 1861, and to "the flourishing empire of Brazil," which ceased to exist in 1889. Again, with regard to the speculation that the Palæozoic rocks may be continuous from the Severn to the Rhine, which is described as of little practical importance, no allusion is made to the discovery of coal at Dover. Mr. Forster Brown, too, omits to point out that the statement that there are very erroneous ideas of the overwhelming importance of the American coalfields as compared with those of Europe is no longer accurate in view of the fact that last year the United States produced more coal than any other country in the world. BENNETT H. BROUGH.

Untersuchungen über die Chemischen Affinitaten. Von C. M. Guldberg und P. Waage. Herausgegeben von R. Abegg. Pp. 182 and 18 tables. (Leipzig: W. Engelmann, 1899.)

THIS latest addition to Prof. Ostwald's invaluable series of reprints will be welcomed by all chemists. The work of Guldberg and Waage is now well known, and is abstracted at some length in the larger books on theoretical chemistry; but we have here the complete series of papers with some recent annotations by Prof. Guldberg, and an interesting biographical and critical notice by Prof. Abegg.

The student of chemical history will do well to read this volume in conjunction with No. 74 of the series, which is a reprint of Berthollet's "Recherches sur la loi d'affinité." Berthollet's work was published in 1801; Guldberg and Waage's first paper is dated 1864. Between these years nothing advancing the mathematical theory of the subject had appeared except the unrecognised paper of Wilhelmy on the rate of inversion of cane-sugar, and the papers of Berthelot on estorification. When this is borne in mind it will be realised how great and how sudden was the advance made by the two Norwegians.

The three papers contained in the reprint, and dated respectively 1864, 1867 and 1879, show how, with the progress of time, the ideas of the authors grew in simplicity and generality, until in 1879 we have their theory in a form differing but little from that in which it is employed at the present day. The two earlier papers were very little known up to 1879, and several investigators worked unwittingly in the same field discovering facts a second time. This, however, can hardly be a matter for regret except in so far as it tends to bewilder the student. In other respects it has only served to strengthen the foundations of chemical dynamics.

A. S.

How to Know the Ferns. By Frances Theodora Parsons. Pp. xiv + 215; and plates. (New York: Charles Scribner's Sons, 1899.)

THIS book is intended to serve as a popular handbook to the ferns of the United States. It will probably fulfil its purpose, in enabling the reader to identify the majority of the ferns described by means of their general habit, aided by the form of the sorus. To this result the numerous original illustrations, which are clear and accurate, will largely contribute. An artificial key to the species is provided, in which the authoress depends to a considerable extent on the degree of difference between sterile and fertile fronds to characterise the main groups. It is to be regretted that attention is not directed to the artificial nature of these distinctions, and that the natural arrangement was not adopted in the part devoted to the description of the species. In this we find the species of *Osmunda* separated in two groups, while the *Ophioglossaceae* are placed in the midst of the true Ferns. The brief account of the reproduction of ferns on pp. 30-35 leaves much to be desired. The figures illustrating this are poor, notably the drawing of a sporangium on p. 31, while the description is bald and in places misleading. No mention is made of the peculiar subterranean prothalli of the *Ophioglossaceae*. Had space been found by the omission of irrelevant matter in the opening chapters for a clear, simply written, and well-illustrated account of the life-history of ferns, with special reference to the native species, the book would have been none the less popular, while its educational value would have been greatly increased. W. H. L.

Laboratory Note-Book for Chemical Students. By Prof. Vivian B. Lewes and J. S. S. Brame. Pp. viii + 170 (with alternate blank pages). (Westminster: A. Constable and Co., 1899.)

THE authors of this book, which is essentially one for the laboratory bench, are of opinion that there is room for a small volume containing all the necessary description for the laboratory preparation of gases, &c., together with the reactions of metallic and acid radicles, in a concise form, and some of the more simple quantitative experiments suitable for students. In the treatment of a few technical matters, such as the valuation of fuel, the simple examination of oils, the viscosity of oils, and the characteristics of explosives, the volume is in advance of most similar laboratory manuals, but the plan of interleaving the text with blank pages for the student's own notes cannot be unreservedly recommended. Many teachers find that such an arrangement is conducive neither to neatness nor originality in the pupil's expression of his own observations. The method has, however, its advantages; and the objection to it does not affect the text, which provides a good course of experimental work in chemistry suitable for technical students and others.

The Elements of Co-ordinate Geometry. "The University Tutorial Series." Part II. The Conic. By J. H. Grace and F. Rosenberg. Pp. viii + 315. (London: W. B. Clive, 1899.)

SO many text-books are available to day that the issue of a new one is generally accompanied by an explanation of its *raison d'être*. The one before us is that the present book seeks to develop the subject in a more gradual and more explanatory manner than its predecessors, and to pay more attention to curve tracing. That it succeeds in this endeavour will be gathered from a perusal of its pages, for no pains seemed to have been spared to lead the reader up small but ever rising steps. To gather a general notion of the scope of the book, we may say that, after briefly describing the three varieties of conics, the student is made acquainted with the general equation of the second degree, and the classification of curves which are represented by such an equation. This is followed by more detailed information relating to various properties of curves, taken at first generally and afterwards individually. The exercises are graduated as much as possible as regards difficulty of solution, and are very numerous.

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